US009126134B2

(12) **United States Patent**
Zhao et al.

(10) **Patent No.: US 9,126,134 B2**
(45) **Date of Patent: Sep. 8, 2015**

(54) **EXHAUST GAS SEPARATING TOWER AND EXHAUST GAS SEPARATING AND RECYCLING SYSTEM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 191 days.

(21) Appl. No.: **14/018,207**

(22) Filed: **Sep. 4, 2013**

(65) **Prior Publication Data**

US 2014/0060333 A1 Mar. 6, 2014

(30) **Foreign Application Priority Data**

Sep. 4, 2012 (CN) 2012 1 0323017

(51) **Int. Cl.**

B01D 47/06	(2006.01)
B01F 3/04	(2006.01)
B01D 47/05	(2006.01)
B01D 47/14	(2006.01)

(52) **U.S. Cl.**

CPC ***B01D 47/05*** (2013.01); ***B01D 47/06*** (2013.01); ***B01D 47/14*** (2013.01); ***B01F 3/04021*** (2013.01); ***B01F 3/04078*** (2013.01); ***B01F 3/04468*** (2013.01); ***B01F 3/04496*** (2013.01); *B01D 2247/107* (2013.01); *B01D 2247/14* (2013.01)

(58) **Field of Classification Search**

CPC B01D 47/06; B01D 47/14; B01F 3/04; B01F 3/04021; B01F 3/04078; B01F 3/04468; B01F 3/04496

USPC 96/243, 290, 296

See application file for complete search history.

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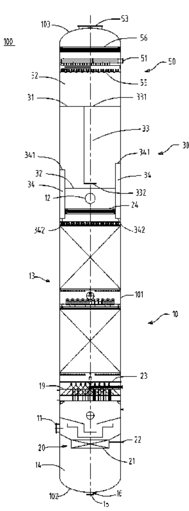
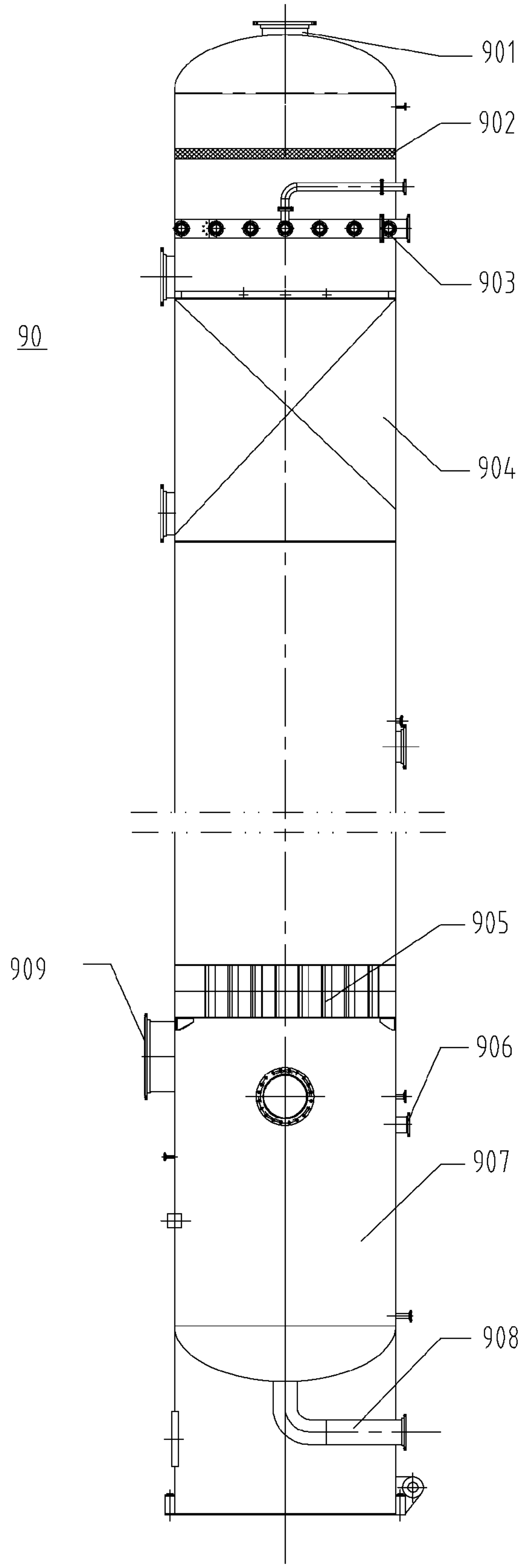
(57) **ABSTRACT**

The invention relates to an exhaust gas separating tower, comprising a washing section, a flash-distilling section above the washing section, and a liquid seal means between the flash flash-distilling section and the washing section. The washing section is configured for washing exhaust gas entering the tower with a cooling liquid to at least partially remove solid dust entrained in the exhaust gas, cool the exhaust gas, and condense at least a portion of moisture in the exhaust gas into liquid. The flash-distilling section is configured for flash-distilling the cooling liquid from the washing section to produce a cooled cooling liquid and a cooling liquid vapor. The liquid seal means is configured so that the cooling liquid produced by flash-distillation can enter the washing section through the liquid seal means while the flash-distilling section is in gas-phase isolation from the washing section, wherein a pressure in the flash-distilling section is lower than that in the washing section.

20 Claims, 6 Drawing Sheets





Prior Art

Fig. 1

Prior Art

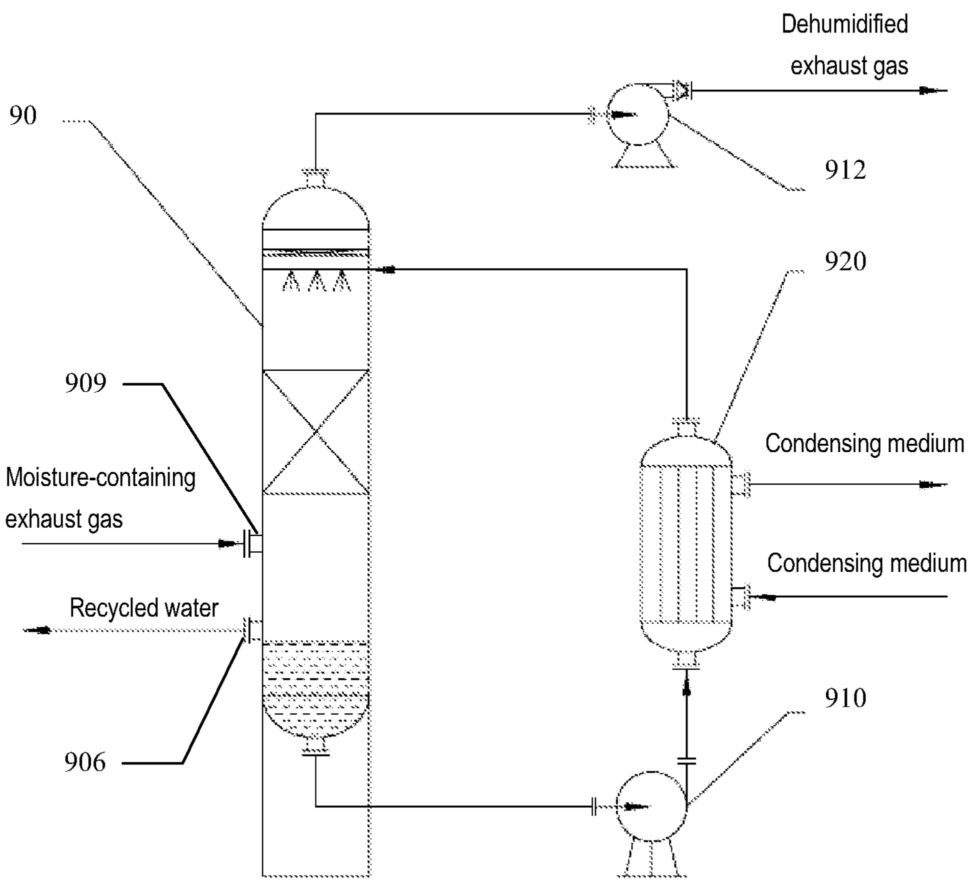


Fig. 2

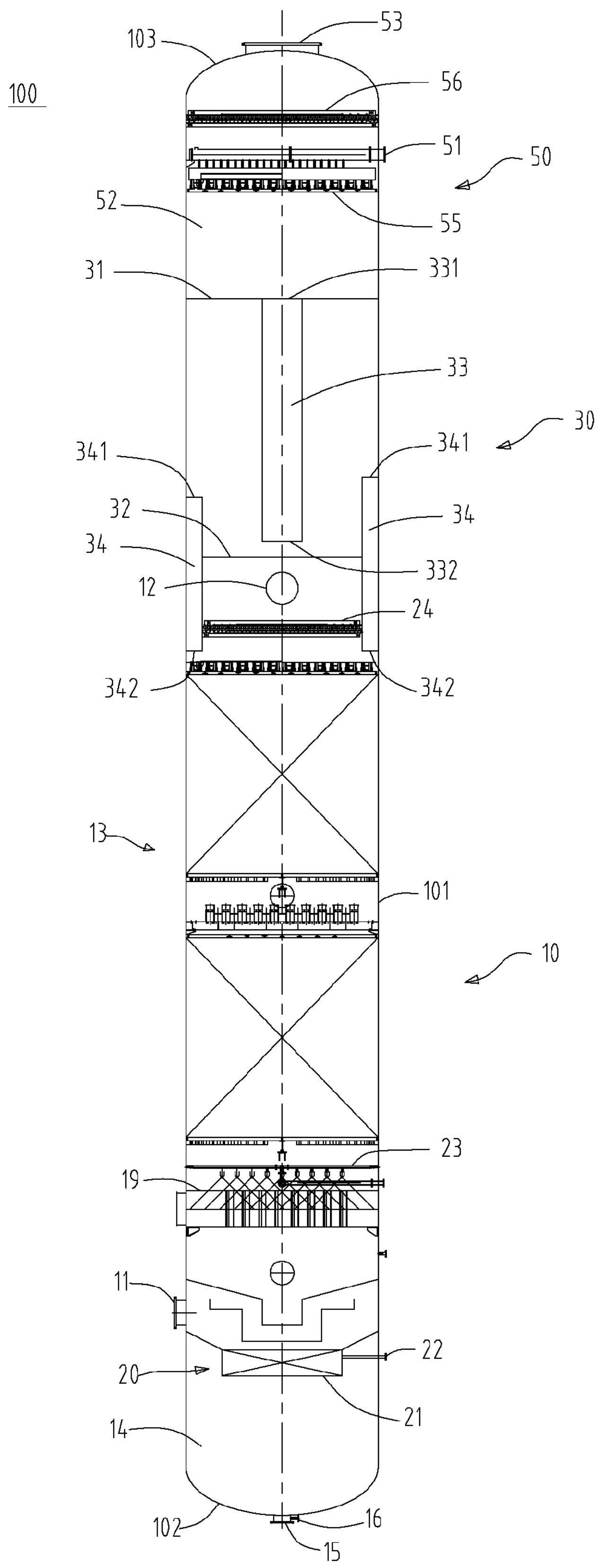

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Fig. 3

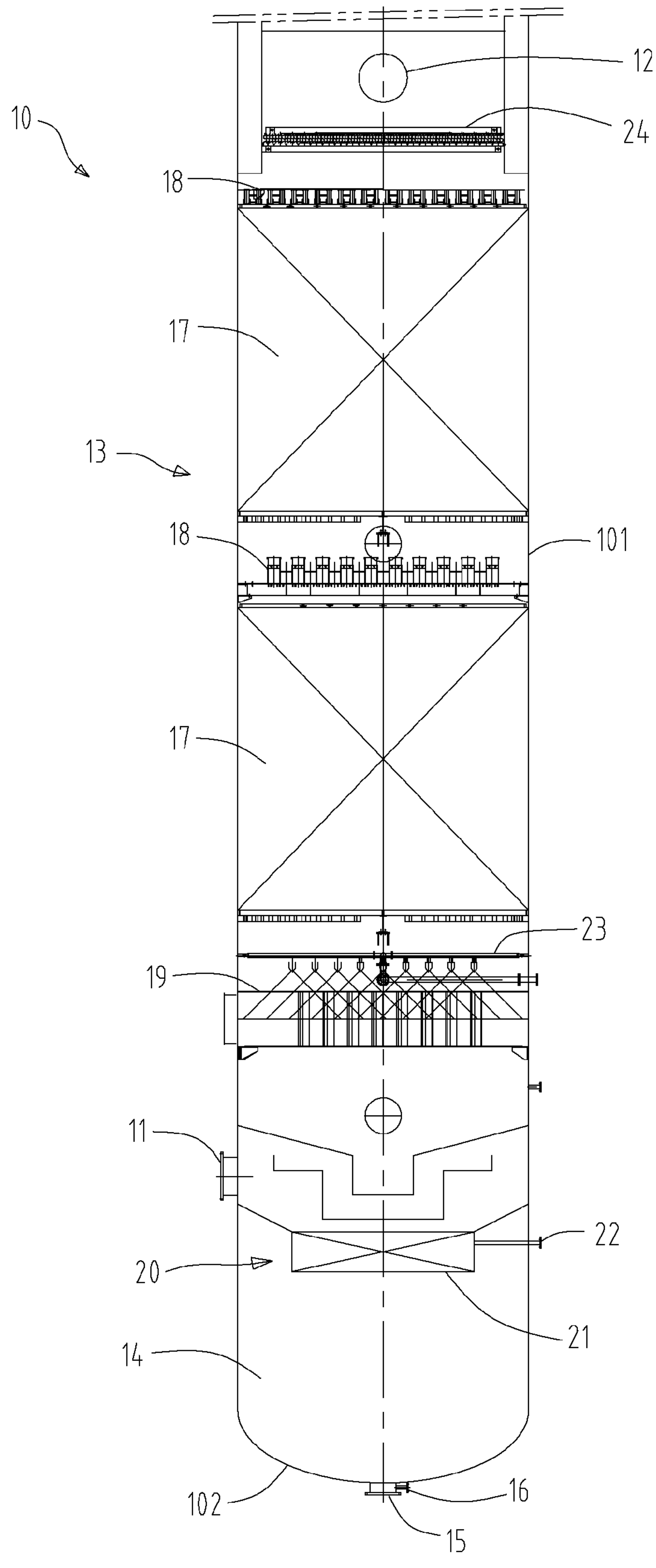
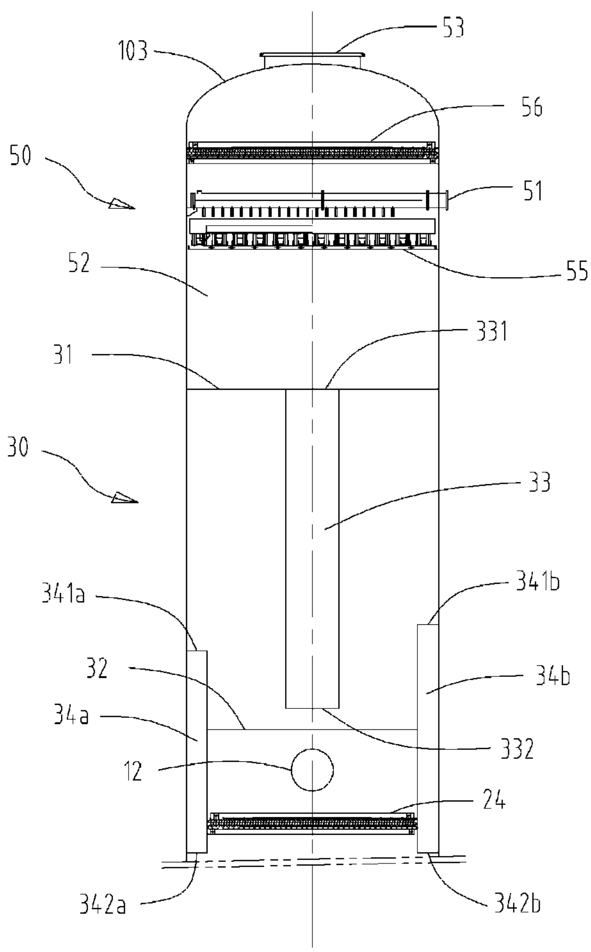


Fig.4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103
56
50
51
52
55
31
331
30
33
341a
341b
32
34b
34a
332
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24
342a
342b

Fig.5

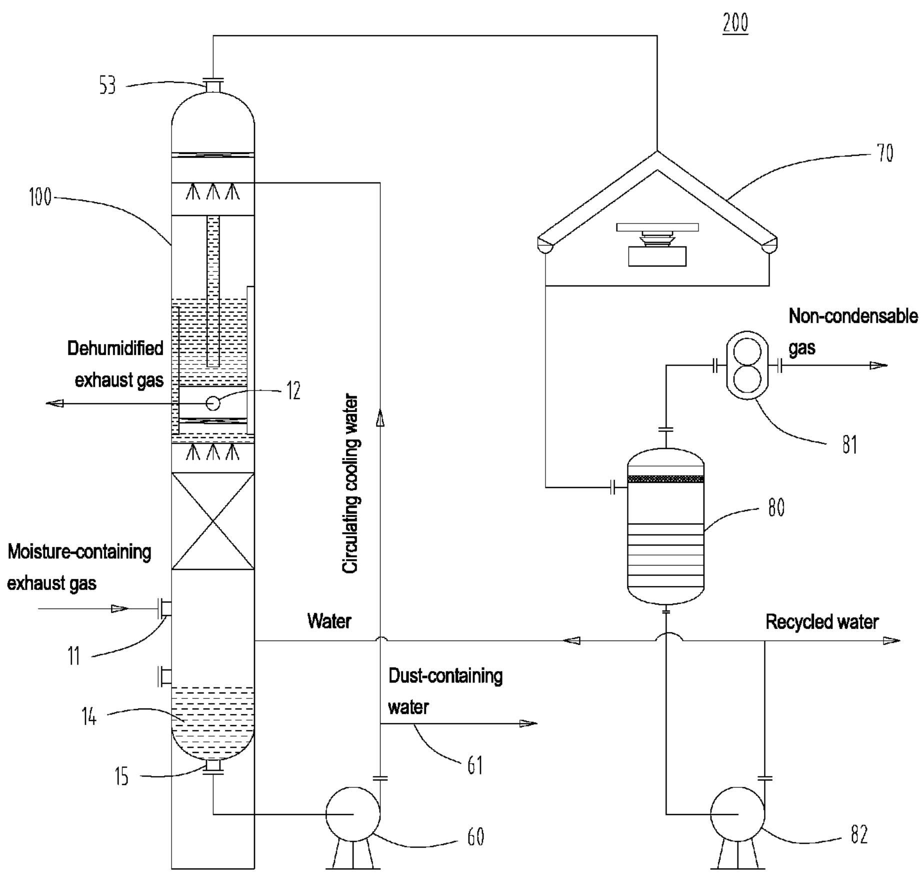
200
53
70
100
Non-condensable gas
Dehumidified exhaust gas
12
81
Circulating cooling water
80
Moisture-containing exhaust gas
Water
Recycled water
11
Dust-containing water
14
61
15
60
82

Fig.6

EXHAUST GAS SEPARATING TOWER AND EXHAUST GAS SEPARATING AND RECYCLING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the priority of Chinese Patent Application No. 201210323017.1 filed on Sep. 4, 2012 and entitled “EXHAUST GAS SEPARATING TOWER”, the entirety of which is incorporated herein by reference.

Some references, if any, which may include patents, patent applications and various publications, may be cited and discussed in the description of this invention. The citation and/or discussion of such references, if any, is provided merely to clarify the description of the present invention and is not an admission that any such reference is “prior art” to the present invention described herein. All references listed, cited and/or discussed in this specification are incorporated herein by reference in their entireties and to the same extent as if each reference was individually incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to an exhaust gas separating tower, and particularly to a separating tower for separating moisture vapors in the exhaust gas from non-condensable gas in the exhaust gas. The present invention also relates to an exhaust gas separating and recycling system for separating the moisture vapors in the exhaust gas from the non-condensable gas in the exhaust gas and recycling the separated moisture vapors.

BACKGROUND OF THE INVENTION

A large quantity of exhaust gas may be produced during industrial processes such as drying and/or pyrolysis processes. The exhaust gas contains not only non-condensable process gases such as air or the like, but also a large amount of moistures including inorganic moistures such as water vapor, or organic moistures such as hexane, methanol, ethanol, and/or acetic acid, and a small amount of solid dust. It is a conventional technique to dehumidify the moisture-containing exhaust gas with a separating tower, such as a washing and cooling tower, to remove the moisture from said exhaust gas, which has been applied widely in process industries, such chemical industry (e.g., petrochemical industry, coal chemical industry, etc.), steel industry, metallurgy industries or the like.

FIG. **1** shows a conventional washing and cooling tower **90**, which comprises from top to bottom: a gas outlet **901**, a gas demister **902**, a liquid dispenser **903**, a filling unit **904** filled with one or more layers of fillers, a gas inlet dispenser **905**, a liquid overflow discharge device **906** and a liquid storage region **907** at a lower part of the tower, and a liquid outlet **908** at the bottom of the tower.

As shown in FIG. **2**, a moisture-containing exhaust gas for example from the drying process enters the washing and cooling tower **90** via a gas inlet **909** adjacent to the bottom of the tower, and rises up to the filling unit **904**. A circulating cooling liquid condensed from the moisture enters the tower from its top, and is evenly sprayed onto the surface of the underlying filler layer through the liquid dispenser **903**. In the filler layer, heat exchange and mass exchange proceed between the exhaust gas and the cooling liquid, which contact with each other in a counter-flowing manner. During this process, the exhaust gas is cooled by the cooling liquid, so

that at least a portion of moisture in the exhaust gas is condensed into liquid and becomes a portion of the cooling liquid; while the exhaust gas is washed by the cooling liquid, so that the solid dust in the exhaust gas is at least partially and preferably totally removed therefrom. After passing through the filling unit **904**, the exhaust gas rises in the tower and reaches the demister **902**, where the exhaust gas is demisted. The demisted exhaust gas is discharged from the washing and cooling tower **90** via the gas outlet **901** by means of an induced draft fan **912**. During the above-mentioned exchanging process, the cooling liquid is heated by the exhaust gas. The cooling liquid that leaves the filler layer falls to reach the bottom of the tower. A portion of the cooling liquid is discharged from the tower **90** through the overflow discharge device **906** at the bottom of the tower or a circulating cooling liquid pump **910** at the outside of the tower, and becomes a recycled moisture liquid that consists of the moisture and the dust. The remaining cooling liquid in the tower is discharged therefrom by the circulating liquid pump **910** via the liquid outlet **908**, and fed into a cooling device **920** by the pump **910** for cooling. The cooled cooling liquid is fed again into the washing and cooling tower **90** to repeat the above processes.

However, such cooling tower in the prior art suffers from the following drawbacks. The recycled moisture liquid obtained from the washing and cooling tower contains not only the liquid condensed from moisture in the exhaust gas, but also solid dust entrained in the exhaust gas. Thus, a further liquid-solid separation process is required to be performed on the recycled liquid, which is technically complex and costly. Furthermore, the dust in the moisture-containing exhaust gas may also enters the circulating cooling liquid, which may block the cooling device during the cooling process for the cooling liquid, and lower the heat exchanging efficiency. Moreover, in order to perform the washing, cooling, and recycling possess, many other apparatuses or devices are needed expect for the conventional washing and cooling tower **90**, so that a large work area is required.

SUMMARY OF THE INVENTION

It is an objective of the invention to provide an exhaust gas separating tower to at least partially overcome or alleviate the drawbacks in the prior art as mentioned above.

It is another objective of the invention to provide an exhaust gas separating and recycling system to at least partially overcome or alleviate drawbacks in the prior art as mentioned above.

To this end, according to one aspect of the invention, an exhaust gas separating tower is provided, which comprises a washing section, a flash-distilling section arranged above the washing section, and a liquid seal means arranged between the flash-distilling section and the washing section. The washing section is configured for washing an exhaust gas entering the tower with a cooling liquid so as to at least partially remove solid dust entrained in the exhaust gas, cool the exhaust gas, and condense at least a portion of moisture in the exhaust gas into liquid. The washing section comprises an exhaust gas inlet, an exhaust gas outlet arranged above the exhaust gas inlet, and a cooling liquid outlet for discharging the cooling liquid having washed the exhaust gas. The flash-distilling section is configured for flash-distilling the cooling liquid from the washing section to produce a cooled cooling liquid to be provided to the washing section and a cooling liquid vapor. The flash-distilling section comprises a cooling liquid inlet through which the cooling liquid from the washing section enters the flash-distilling section, a flash-distilling space for performing flash-distillation therein, and a vapor outlet through which the cooling liquid vapor is discharged. The liquid seal means is configured so that the cooled cooling liquid produced by flash-distillation is able to enter the washing section through the liquid seal means while the flash-distilling section is in gas-phase isolation from the washing section, wherein a pressure in the flash-distilling section is lower than that in the washing section.

According to another aspect of the present invention, an exhaust gas separating and recycling system is provided. The system comprises the exhaust gas separating tower according to the invention as described above. The system further comprises a pump connected between the cooling liquid outlet of the washing section and the cooling liquid inlet of the flash-distilling section, for delivering the cooling liquid that has washed the exhaust gas from the washing section into the flash-distilling section for flash-distillation.

With the exhaust gas separating tower of the invention, moistures in the exhaust gas joins the circulating cooling liquid, and is discharged from the tower in form of cooling liquid vapor via the vapor outlet of the flash-distilling section. The non-condensable gas in the exhaust gas, along with the exhaust gas, is discharged from the tower via the exhaust gas outlet of the washing section. In this way, the moisture vapors and the non-condensable process gas in the exhaust gas can be separated.

With the exhaust gas separating tower of the invention, a clean moisture vapor can be obtained by flash-distillation under a negative pressure. Therefore, a clean recycled liquid can be obtained by condensing said vapor. Thus, the drawback that the recycled liquid from the conventional washing-cooling-absorbing tower contains impurities is avoided. Since the moisture vapor produced by flash-distillation under negative pressure according to the invention is a clean vapor, said vapor will not block other devices such as a condensing heat exchanger. In the separating tower of the invention, the heat for flash-distilling the cooling liquid is from the exhaust gas entering the tower, so that no heat supplement is required for the tower. According to the invention, conventional devices for washing, cooling, absorbing, and flash-distilling are integrated into one tower that requires only small work area.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein:

FIG. **1** is a structural diagram for an existing washing and cooling tower;

FIG. **2** is a flow diagram illustrating dehumidifying processes by using a washing and cooling tower in the prior art;

FIG. **3** is a structural diagram for a separating tower according to an embodiment of the invention;

FIG. **4** is an enlarged schematic view showing a washing section of the separating tower in FIG. **3**;

FIG. **5** is an enlarged schematic view showing a flash-distilling section and a liquid seal means of the separating tower in FIG. **3**; and

FIG. **6** is a schematic view showing an exhaust gas separating and recycling system according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention will now be described in details through following illustrative embodiments. However, it should be understood that an element, a structure or a feature in an embodiment can be beneficially incorporated into other embodiments without further recitation.

Some references, if any, which may include patents, patent applications and various publications, may be cited and discussed in the description of this invention. The citation and/or discussion of such references, if any, is provided merely to clarify the description of the present invention and is not an admission that any such reference is "prior art" to the present invention described herein. All references listed, cited and/or discussed in this specification are incorporated herein by reference in their entireties and to the same extent as if each reference was individually incorporated by reference.

It should also be understood that "comprises/comprising" when used in the specification is taken to specify the presence of stated features, integers, steps or components but dose not preclude the presence or addition of one or more other features, integers, steps or components or groups thereof.

FIG. **3** illustrates an exhaust gas separating tower **100** according to an embodiment of the invention, which comprises a washing section **10** at a lower part of the tower and a flash-distilling section **50** at an upper part of the tower.

Exhaust gas carrying moistures (e.g. water vapor) and solid dust enters the washing section **10** via an exhaust gas inlet **11**. In the washing section **10**, exhaust gas entering the tower is washed by a circulating cooling liquid (e.g. water) to at least partially and preferably totally remove the solid dust in the exhaust gas, lower the temperature of the exhaust gas, and condense at least a portion of the moisture in the exhaust gas into liquid. The condensed moisture liquid becomes a portion of the cooling liquid. The exhaust gas that has been washed is discharged out of the tower via an exhaust gas outlet **12**. The exhaust gas inlet **11** and outlet **12** can be arranged in a sidewall **101** of the tower, wherein the exhaust gas outlet **12** is positioned higher than the exhaust gas inlet **11**. The cooling liquid that has washed the exhaust gas is accumulated at the bottom of the washing section **10**, and can be discharged from the washing section **10** via a cooling liquid outlet **15**.

The flash-distilling section **50** is configured for receiving and flash-distilling the cooling liquid that has been used in the washing section **10**, so as to produce a cooled cooling liquid and a cooling liquid vapor. The cooling liquid from the cooling liquid outlet **15** of the washing section **10** enters the flash-distilling section **50** via its cooling liquid inlet **51**, and is subject to flash-distillation in a flash-distilling space **52** of the flash-distilling section. The cooling liquid vapor produced from flash-distillation can be discharged out of the tower via a vapor outlet **53** of the flash-distilling section. The discharged vapor can be condensed into liquid by a condensing device outside the tower, and the condensed liquid can be recovered and recycled. According to an example of the invention, the cooling liquid inlet **51** can be arranged in the sidewall **101** of the tower and above the flash-distilling space **52**. The vapor outlet **53** can be arranged at the top **103** of the tower.

A liquid seal means **30** is arranged between the flash-distilling section **50** and the washing section **10**. The liquid seal means **30** is configured so that the cooling liquid produced by flash-distillation can enter the washing section **10** via the liquid seal means **30** while the flash-distilling section **50** is in gas-phase isolation from the washing section **10**. In this way, the washing section **10** and the flash-distilling section **50** can be configured to have different internal pressure. Advantageously, the pressure in the flash-distilling section **50** is lower than the pressure in the washing section **10**. Due to such pressure difference, the cooling liquid heated by the exhaust gas in the washing section **10** can be flash-distilled rapidly upon reaching the flash-distilling section **50**. Preferably, the operating pressure in the washing section **10** is set to an atmospheric pressure or a slight positive pressure, while the operating pressure of the flash-distilling section **50** is set to a negative pressure of about 2.5 kPa(A) to about 32 kPa(A).

As shown in FIG. **4**, according to an embodiment of the invention, the washing section **10** comprises a filler segment **13** arranged within the tower, a liquid storage segment **14** at the bottom of the tower **100**, and a cooling liquid outlet **15** extending from a bottom wall **102** of the tower. The filler segment **13** is arranged in a vertical direction between the exhaust gas inlet **11** and the exhaust gas outlet **12**, so that the cooling liquid from the flash-distilling section **50** and the exhaust gas input from the exhaust gas inlet **11** contact with each other in a counter-flowing manner in the filler segment **13**. During such counter-flowing contact, the exhaust gas is cooled by the cooling liquid so that at least a portion of the moistures in the exhaust gas is condensed into liquid and becomes a portion of the cooling liquid, and at the same time at least a portion of solid dust in the exhaust gas is removed from the exhaust gas by washing with the cooling liquid. The liquid storage segment **14** is arranged for storing the cooling liquid falling from the filler segment **13**. The stored cooling liquid can be discharged from the washing section via the cooling liquid outlet **15**, and can further be delivered into the flash-distilling section **50** for example by a pump **60** arranged outside the tower (FIG. **6**). The liquid storage segment **14** can be provided with a liquid discharge means with liquid seal and/or a port with high/low liquid level detector.

The cooling liquid in the liquid storage segment **14** contains fixed dust which is removed from the exhaust gas. According to an embodiment of the invention, a quantitative discharging port **16** branches from the cooling liquid outlet **15**, for quantitatively discharging the cooling liquid stored in the liquid storage segment **14** to maintain the solid dust content in the separating tower **100** within a predetermined range.

According to an embodiment of the invention, the filler segment **13** comprises at least one filling unit **17** with one or more layers of fillers and at least one liquid dispenser **18**, wherein above each filling unit **17** there is one liquid dispenser **18**. The arrangement of the filling unit **17** is arranged for increasing the contact time and contact area between the exhaust gas and the cooling liquid, so that the exhaust gas can be better washed and cooled. The liquid dispenser **18** is arranged for allowing the cooling liquid to evenly fall onto the corresponding filling unit **17**. Two filling units **17** and two liquid dispensers **18** are shown in FIG. **4** for example. Each layer of filler in the filling unit **17** can be for example selected from a bulk filler, a regular filler, a general sieve plate, an oriented sieve plate, and/or a multiple-downspout sieve plate. The liquid dispenser **18** can be for example a conventional liquid distributor for a tower, a mesh-disc-type distributor, a detachable-slot-plate-type gas/liquid distributor, or an overflow-disc-type liquid distributor.

According to an embodiment of the invention, an exhaust gas dispenser **19** is arranged below the filler segment **13**, through which the exhaust gas input from the exhaust gas inlet **11** can be evenly provided to the filler segment **13**. According to an embodiment of the invention, a spraying segment is arranged between the filler segment **13** and the exhaust gas dispenser **19**, for pre-cooling and pre-washing the exhaust gas before it reaches the filler segment **13**. The spraying segment comprises one or more liquid sprayers **23**, which can be conventional sprayers produced by Spraying Systems Co. The liquid used in the sprayer **23** can be the cooling liquid falling from above or provided from the outside of the tower.

Non-condensable gas such as oxygen, and/or nitrogen in the air or like, which is contained in the exhaust gas and is not condensable, may be dissolved in the cooling liquid falling from the filler segment **13**. The presence of such non-condensable gas will increase the quantity of the non-condensable gas precipitated during the subsequent flash-distillation of the cooling liquid. According to an embodiment of the invention, a non-condensable gas removing segment **20** is arranged between the filler segment **13** and the liquid storage segment **14**. The non-condensable gas removing segment **20** comprises a filler layer **21** and a vapor inlet pipe **22** extending from the sidewall **101** of the tower to the filler layer **21**. Thus, vapor with high temperature can enter the filler layer **21** via the vapor inlet pipe **22**, heating the cooling liquid passing through the filler layer **21**. In this way, the non-condensable gas decreases in dissolvability and thus volatilizes from the cooling liquid. Thus, the quantity of non-condensable gas in the cooling liquid entering the flash-distilling section **50** can be minimized The filler in the filler layer **21** can be a bulk filler such as a Pall ring, a ladder ring, or a modified Pall ring, which is made from metal or plastics material; or a regular filler such as a wave mesh filler, or a corrugated filler; or any combination of the foregoing fillers. The vapor with high temperature fed via the vapor inlet pipe **22** can be provided by an external vapor source (not shown).

According to an embodiment of the invention, a gas demister **24** is arranged between the filler segment **13** and the exhaust gas outlet **12**, for removing mist droplets entrained in the exhaust gas before the exhaust gas is discharged from the exhaust gas outlet **12**, so as to further increase the dryness of the discharged exhaust gas. According to the invention, the demister **24** can be a conventional demister, such as a filler-type demister, a screen-type demister, a baffle-plate-type demister, or the like.

Reference is made to FIG. **5**, which shows an enlarged schematic view of the flash-distilling section **50** of the separating tower according to an embodiment of the invention. A cooling liquid dispenser **55** is arranged in the flash-distilling section **50**, which is below the cooling liquid inlet **51** and above the flash-distilling space **52**, so that the cooling liquid from the inlet **51** can be evenly distributed into the underlying flash-distilling space **52**. The cooling liquid dispenser **55** can be for example a conventional liquid distributor for a tower, a mesh-disc-type distributor, a detachable-slot-plate-type gas/liquid distributor, or an overflow-disc-type liquid distributor.

According to an embodiment of the invention, the flash-distilling section **50** is further provided with a demister **56**, for removing the mist droplets in the cooling liquid vapor produced by flash-distillation before said cooling liquid vapor is discharged from the flash-distilling section **50**. The demister **56** is arranged in the top portion of the flash-distilling section **50**, above the cooling liquid inlet **51** and below the vapor outlet **53**. The demister **56** may be a conventional demister, such as a filler-type demister, a screen-type demister, a baffle-plate-type demister, or the like.

Referring to FIG. **5** again, according to an embodiment of the invention, the liquid seal means **30** comprises an upper partition plate **31** and a lower partition plate **32** which are separated from each other. The upper partition plate **31** is arranged at the bottom of the flash-distilling section **50**, while the lower partition plate **32** is arranged at the top of the washing section **10**. At least one first downspout **33** extends downwards from the upper partition plate **31**. The first downspout **33** has a top opening **331** in the upper partition plate **31**, so as to communicate with the flash-distilling section **50**. The first downspout **33** has a bottom opening **332** close to and spaced apart from the lower partition plate **32** by a distance. In this manner, the cooling liquid from the flash-distilling section **50** can flow to the lower partition plate **32** through the first downspout **33**. At least one second downspout **34** extends through the lower partition plate **32**, and has a top opening **341** at a position higher than the bottom opening **332** of the first downspout **33**. Thus, the liquid in the lower partition plate **32** can be accumulated to a height equal to or larger than the distance by which the second downspout **34** extends beyond the lower partition plate **32**. Under this situation, the bottom opening **332** of the first downspout lies below the liquid level, so that the gas in the washing section **10** can not enter the flash-distilling section **50** through the first downspout **33**. The flash-distilling section **50** thus is in gas-phase isolation from the washing section **10**. A bottom opening **342** of the second downspout **34** communicates with the washing section **10**, so that the cooling liquid accumulated in the lower partition plate **32** can enter the washing section **10** via said second downspout **34**. Preferably, the second downspout **34** extends downwards and into the washing section **10** with its bottom opening **342** arranged at a height between the filler segment **13** of the washing section and the gas demister **24** (seeing FIG. **3**).

Preferably, a plurality of second downspouts **34** can be provided, wherein distances between their respective top openings **341** and the lower partition plate **32** are different. As shown in FIG. **5**, for example, two second downspouts **34** are arranged, wherein the top opening **341***a* of the left downspout **34***a* is arranged at a position lower than the top opening **341***b* of the right downspout **34***b*. Thus, when the liquid level of the liquid accumulated on the lower partition plate **32** lies between the opening **341***a* and the opening **341***b*, the liquid can only enter the washing section **10** through the downspout **34***a*. When the liquid level rises to exceed the opening **341***b*, the liquid can enter the washing section **10** through both the downspouts **34***a* and **34***b*. That is, the liquid seal means **30** of the invention can automatically adjust the flow rate of the liquid flowing to the washing section **10** depending on the amount of the liquid accumulated on the lower partition plate **32**. The more liquid is accumulated, the higher the liquid level is, so that the liquid can flow to the washing section **10** through more second downspouts **34**. In contrast, the less liquid is accumulated, the lower the liquid level is, so that the liquid can only flow to the washing section **10** through less second downspouts **34**. When the liquid level is lower than top openings of all second downspouts, the liquid seal means **30** stop providing the cooling liquid to the washing section **10**. It is appreciated that the number of the second downspouts and the height difference among these second downspouts can be set according to practical requirements.

According to another example of the invention, the liquid seal means **30** may be provided with a control valve for controlling the flow rate of cooling liquid from the flash-distilling section **50** to the washing section **10**.

According to an example of the invention, the liquid seal means **30** has a single first downspout **33** arranged at about the center of the cross-section of the tower, and a plurality of second downspouts **34** arranged respectively against the sidewall **101** of the tower. In the case as shown in FIG. **3**, the gas demister **24** in the washing section **10** can be placed in a space surrounded by the second downspouts **34** at the top of the washing section **10**.

Hereinafter, the operation process of the separating tower of the invention will be described by referring to a particular embodiment.

An exhaust gas of about 85° C. to about 150° C. containing solid dust and moisture such as water enters the tower through the exhaust gas inlet **11** of the washing section **10** under the action of an induced draft fan, and then enters the spraying segment **23** through the exhaust gas dispenser **15**. In the spraying segment **23**, the exhaust gas is sprayed with the cooling liquid for pre-washing and pre-cooling. Then, the exhaust gas enters the filling unit **17**. The cooling liquid which has been cooled by flash-distillation is evenly sprayed into the filling unit **17** by the liquid dispenser **18**. In the filling unit **17**, there is a gas-liquid contact between the exhaust gas and the cooling liquid proceeds in a counter-flowing manner, so as to perform heat and mass exchange allowing at least a portion and preferably all of the moisture in the exhaust gas to be cooled into liquid and become a portion of the cooling liquid. The exhaust gas after such counter-flowing contact decreases to a temperature of about 20° C. to about 70° C., and is discharged from the tower via the exhaust gas outlet **12** after being demisted through the gas demister **24**. In this way, the washing, dehumidifying, and cooling process for the moisture-containing exhaust gas is completed.

The cooling liquid is heated by the exhaust gas to about 40° C. to about 100° C. in the filling unit **17** during the counter-flowing contact, and then falls from the filling unit **17** to the non-condensable gas removing segment **20**. After passing through the filler layer **21** to remove the non-condensable gas dissolved in the cooling liquid, the cooling liquid continues to fall and reach the liquid storage segment **14** at the bottom of the tower. A small amount of cooling liquid is discharged quantitatively via the quantitative discharging port **16** through an overflow means at the bottom of the tower or a circulating cooling liquid pump arranged outside the tower and becomes a quantitative discharging liquid, so that the solid dust washed out of the exhaust gas is quantitatively discharged. The remained cooling liquid is fed into an annular space **52** of the flash-distilling section **50** via the cooling liquid inlet **51** by the circulating liquid pump **60** outside the tower.

In the annular space **52**, the cooling liquid with temperature of about 40° C. to about 100° C. is flash-distilled under a negative pressure of e.g. 2.5 to 32 kPa(A), thus producing a cooling liquid with temperature of about 20° C. to about 70° C. and a cooling liquid vapor with temperature of about 30° C. to about 70° C. The cooled cooling liquid reaches the washing section **10** through the liquid seal means **30**, and continues to participate in the washing, cooling, condensing loop for the exhaust gas. The cooling liquid vapor produced by flash-distillation is demisted by the demister **56**, and then leaves the tower **100** via the vapor outlet **53**.

FIG. **6** illustrates an exhaust gas separating and recycling system **200** according to an embodiment of the invention, which comprises the exhaust gas separating tower **100** of the invention as described above. The circulating liquid pump **60** is connected between the cooling liquid outlet **15** of the washing section **10** and the cooling liquid inlet **51** of the flash-distilling section **50**. The cooling liquid which has washed the exhaust gas in the washing section **10** can be delivered by the pump **60** to the flash-distilling section **50** for flash-distillation. In the example shown in FIG. **6**, no quantitative discharging port, but only the cooling liquid outlet **15**, is arranged at the bottom of the tower **100**. In this case, a branch pipe **61** is connected to an outlet of the pump **60** to quantitatively discharge a predetermined amount of dust-containing cooling liquid through the branch pipe **61**, so that the solid dust washed out of the exhaust gas and accumulated in the tower **100** can be quantitatively discharged. Here, the cooling liquid for example can be water.

A condenser **70** is connected to the vapor outlet **53** of the flash-distilling section **50** of the tower, for receiving cooling liquid vapor from the flash-distilling section and condensing the vapor into liquid. The condenser **70** may be air-cooled or water-cooled. The condensed liquid is a clean moisture recycled liquid, which can be delivered to and stored in a storage tank **80** for the use in other processes.

Preferably, an exhaust pump **81** is connected to the top of the storage tank **80**, for discharging the non-condensable gas within the storage tank. Preferably, a recycled water pump **82** is connected to a lower part of the storage tank **80**, for pumping out the condensed liquid in the storage tank **80** as required and delivering said liquid to other device. For example, the condensed liquid can be delivered to the sprayer **23** of the separating tower **100** which is arranged between the filler segment **13** and the exhaust gas dispenser **19**.

Although several preferred embodiments of the present invention have been described, the present invention may be used with other configurations. It will be appreciated by those skilled in the art that, the present invention could have many other embodiments, and changes and modifications may be made thereto without departing from the invention in its broader aspects and as set forth in the following claims and equivalents thereof.

What is claimed is:

1. An exhaust gas separating tower, comprising:

a washing section configured for washing an exhaust gas entering the tower with a cooling liquid so as to at least partially remove solid dust entrained in the exhaust gas, cool the exhaust gas, and condense at least a portion of moisture in the exhaust gas into liquid, the washing section comprising an exhaust gas inlet, an exhaust gas outlet arranged above the exhaust gas inlet, and a cooling liquid outlet for discharging the cooling liquid having washed the exhaust gas;

a flash-distilling section arranged above the washing section and configured for flash-distilling the cooling liquid from the washing section to produce a cooled cooling liquid to be provided to the washing section and a cooling liquid vapor, the flash-distilling section comprising a cooling liquid inlet through which the cooling liquid from the washing section enters the flash-distilling section, a flash-distilling space for performing flash-distillation therein, and a vapor outlet through which the cooling liquid vapor is discharged; and

a liquid seal means arranged between the flash-distilling section and the washing section, so that the cooled cooling liquid produced by flash-distillation is able to enter the washing section through the liquid seal means while the flash-distilling section is in gas-phase isolation from the washing section, wherein a pressure in the flash-distilling section is lower than that in the washing section.

2. The exhaust gas separating tower of claim **1**, wherein the liquid seal means comprises:

an upper partition plate arranged at a bottom of the flash-distilling section;

a lower partition plate arranged at a top of the washing section and separated from the upper partition plate;

at least one first downspout extending downwards from the upper partition plate, wherein each first downspout has a top opening arranged in the upper partition plate to communicate with the flash-distilling section, and a bottom opening close to the lower partition plate;

at least one second downspout extending through the lower partition plate, wherein each second downspout has a top opening arranged at a position higher than the bottom opening of the first downspout, and a bottom opening communicating with the washing section.

3. The exhaust gas separating tower of claim **2**, wherein the liquid seal means further comprises a control valve for controlling a flow rate of the cooling liquid from the flash-distilling section to the washing section.

4. The exhaust gas separating tower of claim **2**, wherein the liquid seal means comprises a plurality of the second downspouts, wherein distances between the top openings of the respective second downspouts and the lower partition plate are different.

5. The exhaust gas separating tower of claim **4**, wherein the first downspout is arranged at about a center of a cross-section of the tower, while the plurality of the second downspouts are respectively arranged against a sidewall of the tower.

6. The exhaust gas separating tower of claim **1**, wherein the washing section further comprises:

a filler segment arranged between the exhaust gas inlet and exhaust gas outlet in a vertical direction, in which the cooling liquid from the flash-distilling section and the exhaust gas input via the exhaust gas inlet contact with each other in a counter-flowing manner; and

a liquid storage segment arranged at a bottom of the tower for storing the cooling liquid falling from the filler segment,

wherein the cooling liquid outlet is arranged at a bottom wall of the tower, via which the cooling liquid in the liquid storage segment is dischargeable.

7. The exhaust gas separating tower of claim **6**, wherein the filler segment comprises at least one filling unit having one or more layers of fillers and at least one liquid dispenser, wherein above each filling unit there is one liquid dispenser.

8. The exhaust gas separating tower of claim **7**, wherein each layer of the filler is selected from a bulk filler, a regular filler, a general sieve plate, an oriented sieve plate, and/or a multiple-downspout sieve plate.

9. The exhaust gas separating tower of claim **6**, wherein the washing section further comprises a non-condensable gas removing segment arranged between the filler segment and the liquid storage segment, the non-condensable gas removing segment comprising:

a filler layer, and

a vapor inlet pipe extending from the sidewall of the tower to the filler layer, via which a vapor can enter the filler layer so as to heat the cooling liquid passing through the filler layer, allowing the non-condensable gas in the cooling liquid volatilize therefrom.

10. The exhaust gas separating tower of claim **6**, wherein the washing section further comprises an exhaust gas dispenser arranged below the filler segment, through which the exhaust gas input through the exhaust gas inlet is able to be evenly provided to the filler segment.

11. The exhaust gas separating tower of claim **10**, wherein the washing section further comprises a spraying segment arranged between the filler segment and the exhaust gas dispenser, for pre-cooling and pre-washing the exhaust gas before the exhaust gas reaches the filler segment.

12. The exhaust gas separating tower of claim **6**, wherein the washing section further comprises a gas demister arranged between the filler segment and the exhaust gas outlet, for removing mist droplets from the exhaust gas before said exhaust gas being discharged via the exhaust gas outlet, wherein a opening of the liquid seal means to the washing section is arranged at a height between the filler segment and the gas demister.

13. The exhaust gas separating tower of claim **6**, wherein the washing section comprises a quantitative discharging port branching from the cooling liquid outlet, through which the cooling liquid in the liquid storage segment is quantitatively discharged to maintain solid dust content in the separating tower within a predetermined range.

14. The exhaust gas separating tower of claim **1**, wherein the cooling liquid inlet of the flash-distilling section is arranged in the sidewall of the tower and above the flash-distilling space;

wherein the flash-distilling section further comprises a cooling liquid dispenser arranged between the cooling liquid inlet and the flash-distilling space, for evenly distributing the cooling liquid input from the cooling liquid inlet into the below flash-distilling space.

15. The exhaust gas separating tower of claim **14**, wherein the vapor outlet of the flash-distilling section is arranged at the top of the tower, the flash-distilling section further comprising a demister for removing mist droplets in the cooling liquid vapor produced by flash-distillation before the cooling liquid vapor being discharged from the flash-distilling section, wherein the demister is arranged below the vapor outlet and above the cooling liquid inlet.

16. The exhaust gas separating tower of claim **1**, wherein the pressure in the washing section is at an atmospheric pressure, while the pressure in the flash-distilling section is about 2.5 kPa(A) to about 32 kPa(A).

17. An exhaust gas separating and recycling system, comprising:

an exhaust gas separating tower, which comprises:

a washing section configured for washing an exhaust gas entering the tower with a cooling liquid so as to at least partially remove solid dust entrained in the exhaust gas, cool the exhaust gas, and condense at least a portion of moisture in the exhaust gas into liquid, the washing section comprising an exhaust gas inlet, an exhaust gas outlet above the exhaust gas inlet, and a cooling liquid outlet for discharging the cooling liquid having washed the exhaust gas;

a flash-distilling section arranged above the washing section and configured for flash-distilling the cooling liquid from the washing section to produce a cooled cooling liquid to be provided to the washing section and a cooling liquid vapor, the flash-distilling section comprising a cooling liquid inlet through which the cooling liquid from the washing section enters the flash-distilling section, a flash-distilling space for performing flash distillation therein, and a vapor outlet through which the cooling liquid vapor is discharged; and

a liquid seal means arranged between the flash-distilling section and the washing section, so that the cooling liquid produced by flash-distillation is able to enter the washing section through the liquid seal means while the flash-distilling section is in gas-phase isolation from the washing section, wherein a pressure in the flash-distilling section is lower than that in the washing section; and

a pump connected between the cooling liquid outlet of the washing section and the cooling liquid inlet of the flash-distilling section, for delivering the cooling liquid that has washed the exhaust gas from the washing section into the flash-distilling section for flash-distillation.

18. The system of claim **17**, wherein the liquid seal means comprises:

an upper partition plate arranged at the bottom of the flash-distilling section;

a lower partition plate arranged at the top of the washing section and separated from the upper partition plate;

at least one first downspout extending downwards from the upper partition plate, wherein each first downspout has a top opening arranged in the upper partition plate to communicate with the flash-distilling section, and a bottom opening close to the lower partition plate;

at least one second downspout extending through the lower partition plate, wherein each second downspout has a top opening arranged at a position higher than the bottom opening of the first downspout, and has a bottom opening communicating with the washing section.

19. The system of claim **17**, further comprising:

a condenser, connected to the vapor outlet of the flash-distilling section, for receiving the cooling liquid vapor from the flash-distilling section, and condensing said vapor into liquid; and

a storage tank, for storing the condensed liquid from the condenser.

20. The system of claim **17**, further comprising:

an exhaust pump connected to the top of the storage tank, for discharging the non-condensable gas within the storage tank; and

a recycled water pump connected to a lower part of the storage tank, for pumping out the condensed liquid in the storage tank.

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